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Can Future Events Influence the Present?

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Abstract

Widom, Srivastava, and Sassaroli [Phys. Lett. A **203**, 255 (1995)] have published a calculation which purports to show that "future events can affect present events". In this note an error in their calculation is identified.

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Widom, Srivastava, and Sassaroli [ref. 1, hereafter called WSS] have recently published a claim that quantum theory implies that "future events can affect present events". WSS analyze an experiment in which photons are incident on a partially reflecting plate, from which they are either reflected toward a detector D_1 or transmitted toward a detector D_2. According to WSS, the counting rate at D_1 can depend on the time at which the photons reach D_2, even in cases in which the counts at D_1 are recorded earlier than the time at which the photons reach D_2. This would seem to imply that one experimenter, by varying the position of D_2, could send a message backward in time to another experimenter located at D_1.

In this note, without addressing the plausibility of this claim, we will point out an error in the calculation done by WSS. We first briefly summarize the argument given by WSS. They consider photons initially heading toward the plate in wave packets called $|\alpha\rangle$ and $|\beta\rangle$. Upon hitting the plate, state $|\alpha\rangle$ evolves into two packets: $|\alpha_1\rangle$ which is heading for D_1 and $|\alpha_2\rangle$ which is heading for D_2. Likewise, state $|\beta\rangle$ evolves into $|\beta_1\rangle$ and $|\beta_2\rangle$. It is essential to the argument of WSS that the photon states $|\alpha\rangle$ and $|\beta\rangle$ not be orthogonal. Defining ϵ to be the overlap of the packets, we can write (as in eq. 3 of WSS)

$$\epsilon = \langle\alpha_1|\beta_1\rangle + \langle\alpha_2|\beta_2\rangle. \tag{1}$$

WSS argue that the counting rate at D_1 can depend on (among other things) the value of ϵ, and that the value of ϵ can depend on the time of arrival of the photons at D_2 (as in eq. 8 of WSS). This would imply that a variation in the time of arrival at D_2 (e.g., a variation in the position of D_2) would affect the counting rate at D_1. To calculate ϵ, WSS approximate the wave packets by plane waves, of frequencies ω_α and ω_β. This introduces factors of $\exp[i(\omega_\alpha - \omega_\beta)t]$ in both terms on the RHS of eq. 1 above; then evaluating ϵ at the times at which the photons arrive at the detectors leads to the claimed result. Fig. 3 of WSS illustrates the calculated dependence of the counting rate at D_1 upon the arrival time at D_2.

Of course, as WSS realize, the packets cannot really be plane waves of distinct frequencies; the condition $\epsilon \neq 0$ requires that the frequency spectra of the packets $|\alpha\rangle$ and $|\beta\rangle$ must overlap. Fortunately, there is no need to use a plane wave approximation, or indeed any approximation, for the time development of the packets. It is exactly true that the value of ϵ, as well as the value of each term on the RHS of our eq. 1, is independent of the time. For example, letting U represent the time-development operator (which for a free wave packet is just a translation at speed c), we can write

$|\alpha_2(t)\rangle = U(t,t_0)|\alpha_2(t_0)\rangle$ and $|\beta_2(t)\rangle = U(t,t_0)|\beta_2(t_0)\rangle$, and so

$$\begin{aligned} \langle\alpha_2(t)|\beta_2(t)\rangle &= \langle\alpha_2(t_0)|U^\dagger(t,t_0)U(t,t_0)|\beta_2(t_0)\rangle \\ &= \langle\alpha_2(t_0)|\beta_2(t_0)\rangle; \end{aligned} \tag{2}$$

thus $\langle\alpha_2|\beta_2\rangle$ is independent of time. In fact, to get the value of ϵ, one need only consider that

$$\epsilon = \langle\alpha|\beta\rangle \tag{3}$$

where $|\alpha\rangle$ and $|\beta\rangle$ are the packets before they have hit the plate.

Either from our eq. 3 (evaluated before the photons hit the plate) or our eq. 1 (evaluated right after they hit the plate) one can see that the value of ϵ does not depend on the time at which the photons reach D_2. This means that eq. 8 of WSS, which does exhibit such a spurious dependence, cannot be correct. Once the initial packets are chosen, the value of ϵ is fixed; it cannot be varied by changing the time of arrival at D_2. Of course one could imagine choosing to take different packets, corresponding to different positions of D_2, but then the influence on the counting rate at D_1 would come from the earlier choice of the packets, not from the (possibly later) choice of the position of D_2.

Therefore the calculation presented by WSS does not support their conclusion that future events can affect present events. Of course, this does not rule out the possibility that their conclusion might nevertheless be correct. If that should turn out to be the case, I will not have to suffer any embarrassment for having written this note; if at some point in the future I learn that the conclusion of WSS was in fact correct, I will merely have to use a mechanism similar to the one they suggest to make sure that this note never did get written!

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References

[1] A. Widom, Y.N. Srivastava, and E. Sassaroli, Phys. Lett. A **203**, 255 (1995).